

THE LEARNING PROCESS IN A SNAIL.¹

IN his well-known experiments (1904), the Russian physiologist Pavlov showed that salivary secretion in a dog, primarily induced by the odour or sight of food, could eventually be induced by a sound or colour which had been for a time synchronised with the primary stimulus. The dog, according to the experiments, was soon able to establish an organic association between the primary and the secondary stimulus. When Pavlov slightly changed the secondary stimulus there was a change in the dog's salivary reaction, and this was taken as evidence of the animal's power to discriminate between stimuli.

With noteworthy clear-headedness, Miss Elizabeth Lockwood Thompson has seen how to apply Pavlov's method to a water-snail, *Physa gyrina*, which glides about in ponds, with foot and mouth upwards, suspended from the surface-film. When a part of the body within a millimetre or two of the mouth is touched with a bit of food, a chewing motion of the mouth-parts is started. With the application of food to near the mouth there was synchronously associated a pressure with a clean glass rod at a fixed distance from the mouth. The next step in the ingenious experiment was to apply the associated or auxiliary stimulus alone in the absence of food, in order to determine from the presence or absence of reactions whether or not an association had been formed between the two sets of stimuli. Miss Thompson deserves to be congratulated, we think, on this extension of Pavlov's method, which he himself did not regard as applicable except to a limited number of mammals. It is now possible, along this line of investigation, to test a snail's power of "learning."

When food was applied to the mouth and at once withdrawn, response followed in 61 per cent. of the tests, the mouth being opened and closed on an average 3.93 times. By means of an apparatus a simultaneous application of pressure to the foot and food to the mouth was secured. In the first 60-110 trials of simultaneous stimuli no response followed; in the remaining trials, out of 250 in all, a response was always given. The snails were thus "trained." After forty-eight hours a response followed the pressure by itself, i.e. in the absence of any food-stimulus, but only for a limited period. Cessation of response to pressure after training is sudden and final. The limit of the effect of training (which simulates memory) is about ninety-six hours. An interesting waning of response (marked by a reduction in the number of mouth movements) was observed in some series of trials; it showed that the snails became adapted to a stimulus which was not followed by its wonted reward. The relation between length of training and training effect (as measured by response to pressure only) requires further investigation.

Miss Thompson also devoted many experiments to inquiring whether the snail could learn to solve a simple U-shaped or Y-shaped labyrinth with a picket fence of wires, one arm leading from near the foot of the tank to the air (the reward), the other not (the punishment). In some cases error was punished by an electric shock, and roughness of the path was used as a warning stimulus. The result was interesting. The snails showed no ability to learn that the one path was to be preferred to the other. But in 15 per cent. of a total of 930 trials in one series, the snails changed their course from the wrong to the right path after contact with a warning stimulus (in this case, slight irritation of the tentacles and the back of the head with a hair) before the shock (punishment) was re-

ceived. There was formed a weak association between two stimuli, the hair and the shock, the former serving as a warning of the punishment to follow if the course be not changed. But the capacity to form associations, already proved by the method of using simultaneous stimuli, does not suffice for the solution of the simplest labyrinth. There was no evidence of "selective" ability.

Miss Thompson has made a very interesting contribution to the study of animal behaviour; the details of the experiments show the punctilious carefulness of her work.

SCREW GAUGES.

THE production of a satisfactory screw gauge is a matter of considerable difficulty as regards both manufacture and testing, and the pamphlet on this subject just issued by the National Physical Laboratory¹ will be found to contain much useful information.

In the case of a plug screw gauge, it is essential that it should enter a standard check ring gauge, but this test is insufficient, since it may be complied with by a plug gauge having such a combination of errors as to enable it to enter the check and yet be useless for the purpose of gauging screws. "Not go" tests are also essential, and certain errors can be detected only by carrying out measurements on the gauge of either a mechanical or an optical character. The full (or major) diameter is measured by use of a micrometer in conjunction with a set of Hoffmann roller gauges. The core (or minor) diameter and the effective diameter are also measured by means of a micrometer, together with a pair of Vee-pieces and a pair of small cylinders respectively. The lathe in which the gauge is machined should be furnished with an attachment for holding the micrometer so that its axis intersects the axis of the gauge at right angles, and arranged so that the instrument can be readily removed. This permits of the gauge being measured as the work proceeds, without the necessity for removing it from the machine. In instruments used for measuring these diameters in the inspection room, the micrometer should be held mechanically so as to comply with the same condition.

The machine described in the pamphlet for measuring the pitch of the screw appears to be both simple and effective. The actual measurement is made by means of a micrometer having a large dial reading to 0.0001 in. An ingenious arrangement, partly mechanical and partly optical, ensures that the axial movement of the micrometer point shall be exactly equal to the pitch of the screw under test. Both periodic and progressive errors in the pitch can be detected from the readings obtained in this machine.

As a general rule, optical measurements of screw gauges cannot be made to the same accuracy as mechanical measurements, but optical methods are of great service from the consideration that the whole of the screwed surface of a gauge can be examined in detail. Errors in angle, want of straightness of the threads, eccentricity between different diameters, and local bumps and hollows can be detected readily by optical means. Until recently, microscopes having cross wires in the eyepiece were alone employed for measurements, and a machine embodying this principle is made by the Cambridge Scientific Instrument Co., and is described in the pamphlet. Such methods have now been displaced to a great extent by a pro-

¹ "An Analysis of the Learning Process in the Snail, *Physa gyrina*, Say." (Behaviour Monographs, vol. iii., No. 3, 1917, pp. 1-89 + 8 plates + 12 tables.) (Cambridge, Mass.)

¹ "Notes on Screw Gauges." By the Staff of the Gauge-testing Department, National Physical Laboratory. Enlarged issue II. (Teddington: W. E. Parrott, The Causeway, 1917.) Price 2s. 6d.

jection machine, which throws on a screen a shadow-like image of the screw thread, magnified a definite number of times. This image is then superposed on a diagram of the correct thread form, drawn to the same magnification. Thus variations from the true form can be seen and measured with a scale. A simple projection apparatus and another having a large field of view are described, together with some convenient accessories.

With the exception of core diameter and pitch, the elements of a screw ring gauge cannot be measured readily. The method of taking plaster casts has been tried, but such casts cannot at present be relied upon to nearer than ± 0.0005 to ± 0.001 in. In general, screw ring gauges are not measured, but tested between limits by "go" and "not go" check plugs, made so as to test each diameter independently.

The pamphlet is written in a very practical manner, and sufficient information and drawings are given to enable anyone interested to set up the various appliances for himself. We are also glad to note that manufacturers who contemplate the installation of measuring instruments, or have experienced difficulties in measurement, are invited to visit the laboratory by appointment to discuss their particular problems with the members of the staff.

MARINE BIOLOGY.

THE twenty-fourth report (1916) of the Danish Biological Station contains two papers of much interest to marine biologists. Dr. C. G. J. Petersen gives a useful account of the development of the external characters in three of the common species of Gobius. The great difficulty there is in discriminating between the young stages of these fishes is well known to those who have handled general collections made in European waters, and Dr. Petersen's careful descriptions will be much appreciated. The second paper in the report is by Dr. H. Blegvad, on the food of fishes in Danish waters within the Skaw. The new feature in this work is that, in addition to an account of the kind of food upon which each species was found to be feeding, the weight of each kind of food found in the fish and the weight of the fish itself were recorded. In this way a more accurate idea of the relative importance of the different kinds of food can be obtained.

In the Marine Biological Report, No. iii., 1916, for the province of the Cape of Good Hope, Dr. J. D. F. Gilchrist, in the first paper, describes the eggs and larvæ of a number of Cape fishes. Unfortunately the figures which accompany this paper appear to have lost a great deal in the reproduction, and many of them can scarcely be considered adequate for recognising these very delicate forms, the identification of which often depends on a correct representation of their minute details. The remainder of the report contains an account of some observations on marine invertebrates, made on animals living in the tanks of the Marine Station at St. James, the description of four new South African fishes, which are well figured, and a continuation of Mr. W. Wardlaw Thompson's "Catalogue of Fishes of the Cape Province," with a very full bibliography of each species.

THE DEVELOPMENT OF BRITISH AGRICULTURE AND FISHERIES.¹

THE advances recommended during the year amounted to 334,903*l.* Since the commencement of the war advances from the Development Fund have been mainly confined to schemes already established with the expectation of continued help from the fund,

¹ Abstracted from the seventh report of the Development Commissioners on their proceedings during the year ended March 31, 1917.

for which just sufficient advances have been recommended to secure continuity.

As regards new schemes, the Commissioners have continued to recommend expenditure upon the preparation, by way of preliminary surveys and reports, of projects of development for commencement after the war when the employment of labour upon a large scale may be desirable. They have also recommended expenditure on certain new schemes in order to meet war conditions, particularly in connection with food supply and natural products. The two most important new advances recommended by them during the year, namely, 125,000*l.* for purchase of an estate for sugar-beet growing, and 50,000*l.* for improving the fish food supply by installing motors in fishing-boats in England and Wales, fall under this heading. These two advances amount to one-half of the whole sum recommended for the year. A largely increased supply of plants for afforestation purposes, and increased growings of flax for aeroplane cloth, are other instances where war conditions have called for extra expenditure from the Development Fund.

AGRICULTURE AND RURAL INDUSTRIES.

Agricultural Research and Education, etc.—For the continuance of the research scheme in England and Wales during 1917–18 the following grants from the Development Fund to the Board of Agriculture and Fisheries have been sanctioned:—

Grants to colleges and institutions in aid of—		£
(a) Scientific research and experiments ...	19,600	
(b) The extension of advisory and local investigation work ...	8,000	
(c) Special investigations and research, and scholarships ...	2,400	
(d) Inquiries and experiments, etc., by or on behalf of the Board ...	600	
Expenses of administration ...	880	
		31,480
Less amount not payable from the Development Fund ...	1,750	
		29,730

Research in animal pathology to be undertaken at the Board's veterinary laboratory, 1917–18 ...	2,000
Research Institute in Plant Pathology at Kew ...	1,358

The proposed expenditure in respect of the grants for research institutes and advisory centres contemplates only the carrying on of existing work, and no new work of any importance was started last year with the exception of investigations bearing directly on the war, with which some of the workers are engaged, particularly at Cambridge University.

A grant to the Board of Agriculture and Fisheries of 16,445*l.* was made in aid of agricultural and dairy education during the year 1917–18.

A grant of 3700*l.* was sanctioned to enable the Board in consultation with the Commissioners to assist new emergency schemes of an educational or quasi-educational character. A grant of 1330*l.* was made to the Imperial College of Science and Technology for an investigation during 1917 into the effect of electrical discharge on the growth of crops.

The Commissioners have recommended an advance of 400*l.* to the North of Scotland College of Agriculture for the continuation during 1916–17 of research work which is being carried out under the supervision of a joint committee of the University of Aberdeen and of the college; an advance of 315*l.* to the University of Edinburgh for the continuation during the period